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IS 1448-97 (1980): Methods of test for petroleum and its products, Part 97: Thermal oxidation stability of aviation turbine fuels (JFTOT method) [PCD 1: Methods of Measurement and Test for Petroleum, Petroleum Products and Lubricants]

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IS : 1448 [P : 97] - 1980
Adopted : 8 May 1980

(Reaffirmed 2003)

Indian Standard

METHODS OF TEST FOR PETROLEUM AND ITS PRODUCTS

[P : 97]

THERMAL OXIDATION STABILITY OF AVIATION TURBINE FUELS (JFTOT METHOD)

UDC 665·743 : 543·876·06

Adapted with permission from joint publication ASTM Designation: D 3241-77/IP 323/75

1. SCOPE

1.1 This standard prescribes a procedure for rating the tendencies of gas turbine fuels to deposit decomposition products within the fuel system.

2. OUTLINE OF THE METHOD

2.1 This method for measuring the high temperature stability of gas turbine fuels uses the Jet Fuel Thermal Oxidation Tester (JFTOT) which subjects the test fuel to conditions which can be related to those occurring in gas turbine engine fuel systems. The fuel is pumped at a fixed volumetric flow rate through a heater after which it enters a precision stainless steel filter where fuel degradation products are trapped.

2.1.1 The apparatus requires 600 ml of test fuel for a 150-minute test. The essential data derived are the amount of deposits on an aluminium heater tube and the rate of plugging of a 17 μm nominal porosity precision filter located just downstream of the heater tube.

3. SIGNIFICANCE

3.1 The test results are indicative of fuel performance during gas turbine operation and can be used to assess the level of deposits that form when liquid fuel contacts a heated surface that is at a specified temperature.

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NEW DELHI 110002

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4. APPARATUS

4.1 Jet Fuel Thermal Oxidation Tester (JFTOT)* — Either recording model or non-recording model may be used. Both models are of the same size; 914 mm high, 762 mm wide, and 305 mm deep and designed to sit upon a standard height chemical laboratory bench. Appendix A gives a detailed description of the apparatus (*see* Note).

NOTE — No attempt should be made to operate the JFTOT without first becoming acquainted with all components and the function of each.

4.2 Heater Tube Deposit Rating Apparatus — The amount of deposits on the heater tube are rated by either the Mark 8A Tube Deposit Rater* or a Tuberator† and the ASTM colour standard‡.

4.3 Materials, Supplies and Spares — These are listed in Appendix B.

5. STANDARD OPERATING CONDITIONS

5.1 Fuel Quantity — 600 ml.

5.2 Fuel Pre-treatment — Filtration through a single layer of general purpose, retentative, qualitative filter paper followed by a 6 minutes aeration at 1·5 l/min air flow rate.

5.3 Fuel System Pressure — 3·45 MN/m^2 (MPa).

5.4 Maximum Heater Tube Temperature — Preset as specified for the fuel under test.

5.5 Fuel Flow Rate — 3·0 ml/min.

5.6 Test Duration — 150 minutes.

6. PREPARATION FOR TEST

6.1 Disassembly — All the steps required for disassembly of the test section are given in **8**.

6.2 Calibration of Heater Tube Temperature Controller

6.2.1 The AutoCal Calibrator is used for calibrating the heater tube temperature controller. This calibrator is a nickel-plated heater tube which has a small well containing pure tin. This method utilizes the freezing point of tin, 232°C, as the standard calibration temperature.

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*Available from ALCOR Inc., 10130, Jones-Maltsberger Road, P.O. Box 32516, San Antonio, Texas 78284, USA.

†Tuberator light box, Part OIFC-8004 is available from Erdco Engineering Corporation Addison, Illinois 60101, and is identical to the tuberator used in IS: 1448 [P: 49]-1962 'Test for thermal stability of aviation turbine fuels'. The JFTOT tube adapter and magnifying assembly for use with the tuberator is available from ALCOR, Inc.

‡The ASTM colour standard for tube deposit rating may be purchased from ASTM Headquarters, 1916 Race Street, Philadelphia, Pa 19103. Request Adjunct No. 12-416600-00.

6.2.2 Install the AutoCal Calibrator by placing the hollow end of the calibrator flush with the top surface of the upper fixed bus-bar and tighten both socket head (Allen) screws.

6.2.3 Secure the plugged end of the calibrator by raising the lower floating bus-bar to the upper limit of its travel and tighten both socket head (Allen) screws.

6.2.4 Lower the thermocouple through the upper section of the calibrator and coat the thermocouple tip with silicone grease to prevent sticking to tin.

6.2.5 Lower the thermocouple into the well to press lightly against upper surface of the solid tin.

6.2.6 Set digital readout on 'Heater tube temperature control' at 232.

6.2.7 Set 'power control' at zero.

6.2.8 Switch the 'control mode' to MANUAL position.

6.2.9 Switch the 'power control' to ON.

6.2.10 Check that water pressure indicator is in green arc. Adjust the 'water flow controllers' so that the indicator is in green arc (this corresponds to 38±8 l/h).

6.2.11 Switch 'autocal control' to ON.

6.2.12 Switch 'heater control' to ON.

6.2.13 Set 'power control' at 75 to 80 setting (*see* Note).

NOTE — A higher setting may be required for some instruments. First ensure good contact at low voltage connections and then, if required adjust removable stop at rear of power controller (*see* **A-4.2**).

6.2.14 Wait at least 2 minutes before proceeding with the calibration check to allow for temperature stabilization and warm-up of the temperature controller.

6.2.15 Depress AUTOCAL pushbutton for 3 seconds and observe the deviation meter needle of the 'heater tube temperature control'. Repeat at short intervals until the deviation meter needle swings to full right. This indicates that the tin is molten.

6.2.16 While the temperature deviation meter needle is deflected full right, carefully lower the thermocouple to the bottom of the well, noting the total distance of travel on the thermocouple positioning indicator and then raise it 2·5 mm. Be sure the thermocouple is centered in the well (*see* Note).

NOTE — If the travel of the thermocouple is not at least 5 mm, refill the well with a new charge of tin pellets in accordance with the instructions in Appendix E and repeat as above, starting with **6.2.2.**

6.2.17 If the temperature deviation meter needle is less than full right, depress AUTOCAL button until the needle is again full right scale deflection and then release. The deviation meter needle will slowly move from right to left, stop, and then abruptly reverse to the right and pause for about 3 to 5 seconds. During the time the needle is paused, adjust the digital readout to center the needle. The pause period constitutes the freezing point, the change of state from liquid to solid tin. The drop in temperature below the freezing point and abrupt reversal is due to the supercooling characteristic of tin (*see* Fig. 1). If the deviation meter needle does not remain completely stationary for a minimum of 3 seconds, the tin is contaminated and needs replacement (*see* Appendix E for replacement instructions).

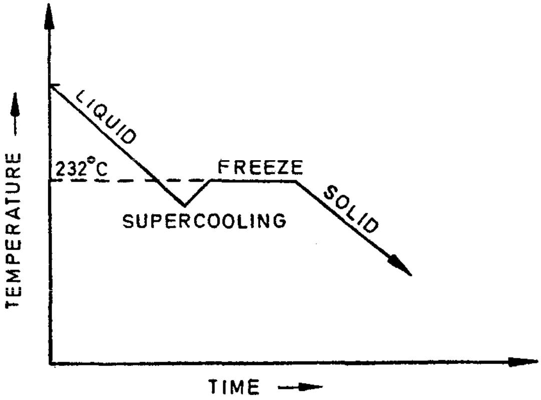


FIG. 1 FREEZING CHARACTERISTICS OF TIN

6.2.18 Repeat this procedure as necessary until the deviation meter needle is centered during pause without the need for adjustment of the controller digital setting. Observe and record on a data sheet (*see* Fig. 2) the 'indicated melting point', that is, the digital setting to center the needle during the pause.

6.2.19 When the 'indicated melting point' has been satisfactorily determined, remelt the tin by depressing the AUTOCAL pushbutton to obtain a full right-scale deflection of the temperature deviation meter needle. Then release the pushbutton and immediately raise the thermocouple tip so as to be accessible and remove all residual traces of silicone and tin by wiping the tip with paper tissue. Inspect the tip closely for cleanliness.

6.2.20 Switch 'heater control' to OFF.

6.2.21 Switch AUTOCAL 'control' to OFF.

THERMAL OXIDATION STABILITY TEST
USING
JET FUEL THERMAL OXIDATION TESTER

Date ....Fuel Description...........Test No......

Name of Testing Laboratory...

CONTROLLER CALIBRATION

Indicated Melting Point, °C.......

True Melting Point, 232°C........

Controller Error................

Maximum Heater Tube Temperature

Specified, °C.................

Controller Error, °C..........

Controller Setting, °C.........

CLOCK TIME

Fuel Aerated...................

Heater On..................

FUEL TEMPERATURE AT AERATION.......................

FILTER PRESSURE DROP DATA

Test Time, Minutes	*Filter △P* mm Hg	*Recorded* △P mm Hg	*Test Time, Minutes*
0	....	2	....
30	....	10	....
60	....	15	....
90	....	25	....
120	....	50	....
150	....	75	....
....	250	125	....

HEATER TUBE DEPOSIT DATA

Maximum Visual Deposit Rating, ASTM Code No................

Maximum Mark 8A TDR Spun Deposit Rating

Maximum Mark 8A TDR Spot Deposit Rating

Remarks ....

FIG. 2 JFTOT DATA SHEET

6.2.22 Raise the thermocouple to the extreme upper limit and remove the AUTOCAL Calibrator.

6.3 Inspection of Components

6.3.1 Inspect the reservoir cover O-ring for cuts, abrasion, and excessive swelling and replace as necessary.

6.3.2 Inspect all O-rings used on all line fittings, including those on nitrogen and fuel return lines, for cuts, abrasion, and excessive swelling and replace as necessary.

6.3.3 Inspect the ceramic insulators and replace if they are cracked or chipped.

6.3.4 Inspect all stainless steel components for damage and replace as necessary.

6.4 Inspection and Testing of Reservoir Piston Lip Seal

6.4.1 Inspect the lip seal for cuts, abrasion, or excessive swelling and replace as necessary.

6.4.2 When required to install a lip seal on the piston, be sure the inner lip is properly placed under retaining shoulder of piston. *See* Fig. 3 for proper lip seal assembly position.

6.4.3 With the thumbs, gently push the sealing edge of the lip seal outward from the centre of the reservoir piston while slowly rotating the piston in the hands. This will minimize leaks past the seal.

6.4.4 Attach the piston puller to the piston. Wet the lip seal and reservoir wall with jet fuel and insert the piston so that the top of the lip seal is about 25 mm from the top of the reservoir.

6.4.5 Close the outlet of the reservoir with the cap seal.

6.4.6 Pour the jet fuel on top of the piston to a depth of 6 mm.

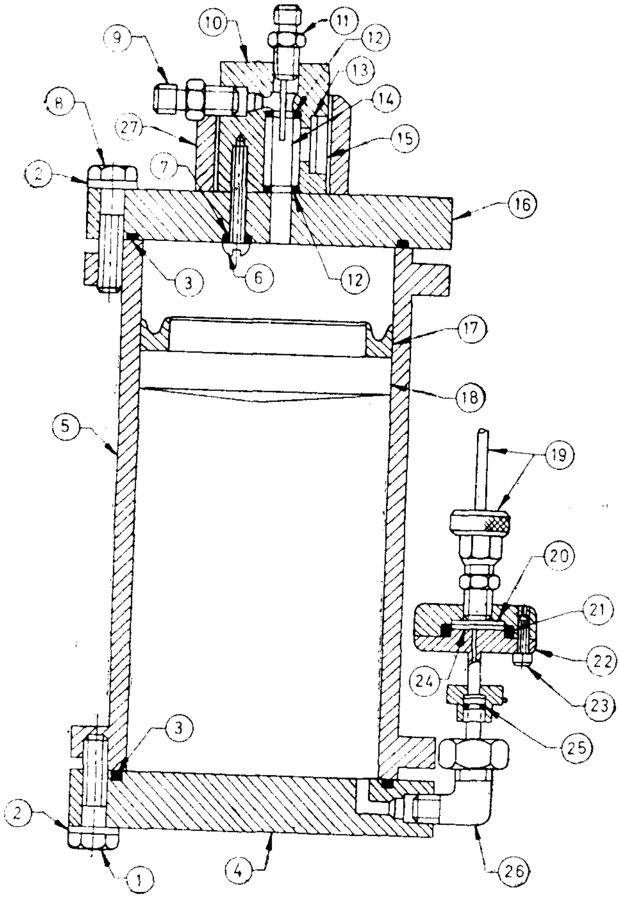
6.4.7 Press downward on the piston puller until air leaks past the lip seal as evidenced by air bubbles.

6.4.8 Release the pressure and observe whether air leakage past the lip seal stops. Change to a new lip seal if the air leakage does not stop immediately.

6.4.9 Remove the cap seal at the outlet and observe whether the piston moves downward with the piston puller in place. Change to a new lip seal if the piston does not move downward and repeat the lip seal test procedure, commencing with **6.4.2**.

6.5 Cleaning

6.5.1 Put on protective gloves because of the possibility of skin irritation from solvents.



1. Cap screw, hex head
2. Washer
3. O-Ring seal, reservoir
4. Base
5. Cylinder
6. Screw, truss head
7. O-Ring seal, ret. screw
8. Cap screw, hex head
9. Nitrogen inlet fitting
10. Housing, drip flow indicator
11. Drip tube fitting
12. O-Ring seal, sight glass
13. Retaining ring
14. Sight glass
15. Window glass
16. Cover
17. Lip seal
18. Piston
19. Heater tube fuel supply line assy
20. Filter backup screen
21. O-Ring seal, pre-filter
22. Housing, pre-filter
23. Cap screw, allen head
24. Membrane filter
25. O-Ring seal
26. Reservoir fuel outlet fitting
27. Protector, sight glass

FIG. 3 RESERVOIR AND PRE-FILTER ASSEMBLY

6.5.2 Position the cleaning pan to catch solvent during cleaning operations.

6.5.3 Place a new piece of aluminium foil about 450 mm square on the bench for placing all test section components after cleaning.

6.5.4 Using the wash bottle filled with hexane, flush the reservoir cover O-ring.

6.5.5 Flush all inside surfaces of the reservoir with hexane while scrubbing the surface with nylon brush.

6.5.6 Flush all inside surface of the reservoir with hexane without brushing, and set the reservoir upside down on aluminium foil.

6.5.7 Using a squeeze bulb, blow out the reservoir fuel outlet exit fitting on the bottom of the reservoir to remove remaining hexane.

6.5.8 Handling the reservoir piston by a piston puller, repeat **6.5.4** and **6.5.5** for the reservoir piston, being careful not to brush or damage the lip seal.

6.5.9 Flush reservoir cover assembly with hexane.

6.5.10 Flush heater tube fuel supply line and heater tube fuel outlet line with hexane and thoroughly blow dry using a squeeze bulb.

6.5.11 Flush the pre-filter components with hexane.

6.5.12 Using a nylon brush saturated with trisolvent, brush the inside surfaces of the heater tube housing (*see* Note).

NOTE — This is the only component that requires cleaning with trisolvent (*see* **B-4.7**).

6.5.13 Flush the heater tube housing and filter bypass line with hexane and blow dry with a squeeze bulb. Visually inspect the inner surfaces of the heater tube housing for cleanliness and repeat **6.5.12** as required to remove all deposits.

6.5.14 Flush the four ceramic insulators and heater tube housing nuts with hexane.

6.5.15 Flush the glass filter funnel and glass aeration tube with hexane.

6.6 Assembly of Heater Tube Section

6.6.1 New heater tube, test filter, and three new high temperature O-rings are required for each test*.

6.6.2 During assembly be sure to have *clean* hands or wear clean, dry gloves.

6.6.3 Holding the heater tube at one end, carefully insert it into the heater tube housing. Note that the open end of the heater tube shall be oriented up, to permit thermocouple insertion while the lower end is plugged by a drive screw (*see* Fig. 4) for proper heater tube section assembly (*see* Note).

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*Available from ALCOR Inc., 10130 Jones-Maltsberger Road, P.O. Box 32516, San Antonio, Texas 78284.

NOTE — *If the centre test section is touched, reject the tube as it will affect the deposit-forming characteristics on the tube.*

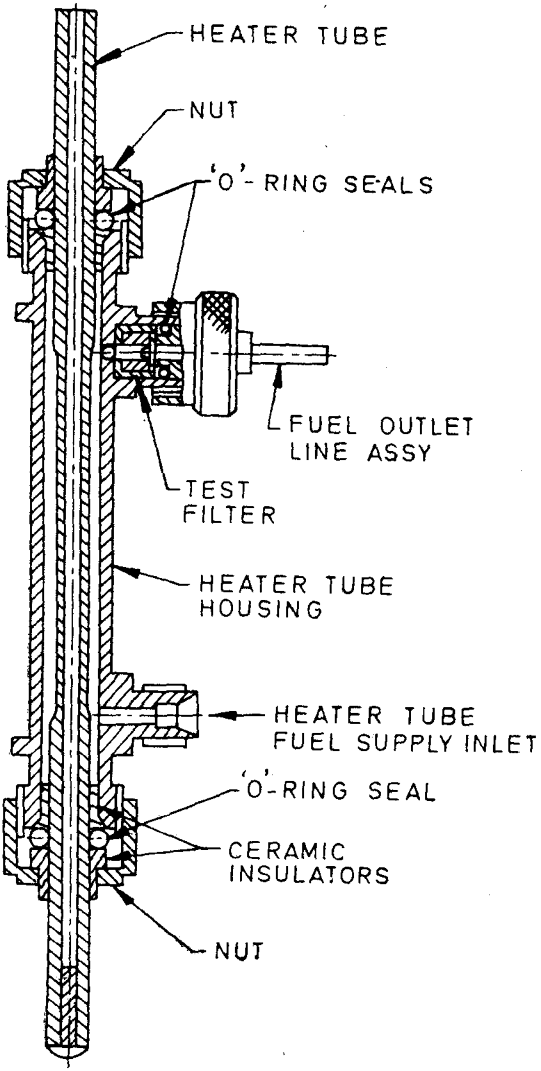


FIG. 4 ASSEMBLY DRAWING OF HEATER TUBE SECTION

6.6.4 Onto one end of the heater tube, sequentially install a flared ceramic insulator (flared end out), high temperature O-ring, shoulder ceramic insulator (large end first), and hexagon nut. Lightly finger tighten nut with the heater tube approximately centered in the housing (*see* Fig. 4).

6.6.5 Repeat the above procedure for the other end of the heater tube.

6.6.6 Observe the heater tube through the fuel discharge hole of the heater tube housing. Align heater tube shoulder with the centre of the fuel discharge hole (*see* Fig. 5). Tighten the hexagon nuts firmly with fingers only. *Do not use a wrench.*

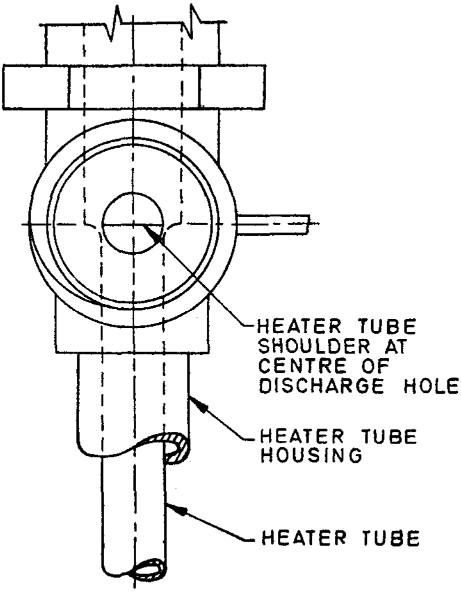


FIG. 5 ALIGNMENT OF HEATER TUBE

6.6.7 Using clean tweezers, install the test filter *red coloured side out,* in the outlet chamber of the heater tube housing.

6.6.8 Place a new O-ring on top of the test filter, pushing the O-ring in until it bottoms against the filter.

6.6.9 Connect the fuel outlet line assembly to the heater tube housing outlet. Finger tighten lightly.

6.6.10 Using paper tissue wet with hexane, clean the contact areas of bus-bars.

6.6.11 Raise the thermocouple to the upper-most position.

6.6.12 Place the heater tube test section between bus-bars. Check the alignment, connect and tighten the heater tube fuel outlet and bypass lines to the bulk head fittings on the rear wall of the test section being sure that the O-rings on these fittings are in place.

6.6.13 If the bus-bars caps have been removed, check for proper mating. Numbers are stamped on inside faces and these shall be the same and shall face each other (*see* Note).

NOTE — Normally the caps are not removed entirely from their respective bus-bars during disassembly.

6.6.14 Tighten both socket head (Allen) screws of the upper fixed bus-bars cap after making sure that upper end of the heater tube is flush with the top surface of the upper fixed bus-bar.

6.6.15 Raise the lower floating bus-bar until it touches the lower ceramic insulator of the heater tube test section and tighten both socket head (Allen) screws of the lower floating bus-bar cap.

6.6.16 Check the thermocouple for proper position by raising the position indicator to the thermocouple reference line (*see* Fig. 6). The thermocouple tip shall be flush with the top of the heater tube and the top of the upper fixed bus-bar. If not, *see* Appendix E.

6.6.17 Insert the thermocouple into the upper end of the heater tube and lower to 38·7 mm position.

6.7 Assembly and Installation of Pre-filter

6.7.1 For each test, use a new 0·45 μm membrane filter element of 25 mm diameter.

6.7.2 Using clean flat-bladed unserrated tweezers, install the filter element back-up screen in the pre-filter housing recess.

6.7.3 Using clean tweezers, place the 0·45 μm membrane filter element on the back-up screen in the pre-filter housing recess.

6.7.4 Install the O-ring on the other half of the pre-filter housing.

6.7.5 Assemble the two housing sections, insert the three screws and tighten.

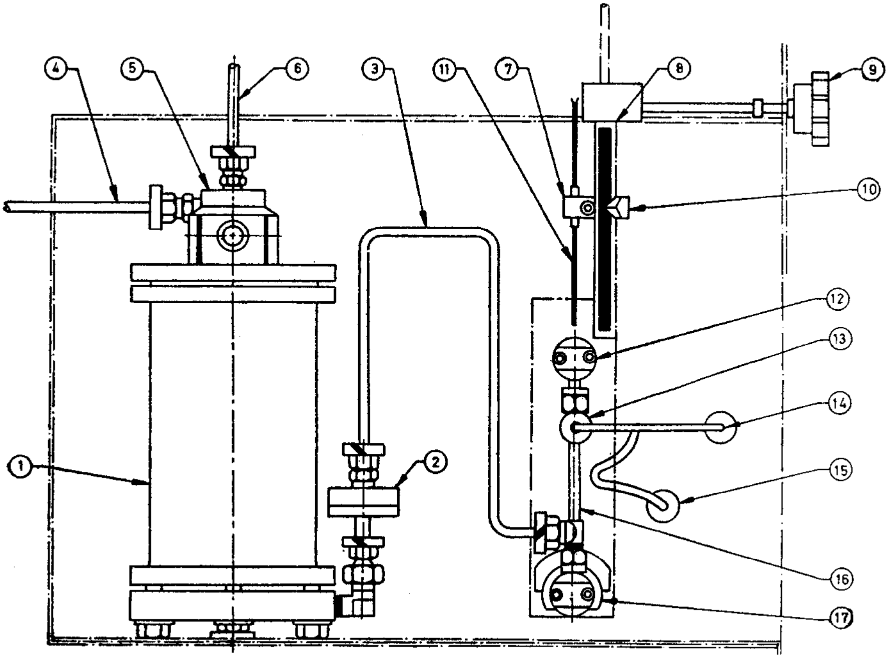
6.7.6 Connect the pre-filter assembly to the reservoir outlet and finger tighten snugly.

6.7.7 Connect the heater tube fuel supply line to pre-filter and finger tighten snugly.

6.7.8 Install cap seal at end of heater tube fuel supply line.

6.8 Preparation of Test Fuel

6.8.1 Place a general-purpose, retentive, qualitative filter paper into a glass funnel and set the funnel into funnel holder that attaches to the reservoir.



1. Reservoir
2. Prefilter
3. Heater tube fuel supply line
4. Nitrogen inlet lion
5. Drip flow indicator
6. Spent fuel return line
7. Thermocouple clamp
8. Thermocouple reference line
9. Thermocouple position control
10. Thermocouple position indicator
11. Thermocouple
12. Upper fixed bus
13. Test filter housing
14. Heater tube fuel outlet line
15. Filter bypass line
16. Heater tube housing
17. Lower floating bus

FIG. 6 TEST SECTION COMPARTMENT

6.8.2 Measure 600 ml of fuel using clean graduated cylinder (*see* Note).

NOTE — Because it is necessary to have the test fuel at 15 to 32°C after filtration, it is desirable to have the test fuel within the temperature range at this time.

6.8.3 Pour the test fuel into the filter and allow the fuel to flow into the reservoir.

6.8.4 Remove the funnel holder.

6.8.5 Insert a clean glass thermometer to measure the temperature of the test fuel. The test fuel shall be between 15 and 32°C. If the test fuel temperature is outside of these limits, a suitable way to change the temperature is to set the reservoir containing the filtered test fuel into a hot or cold water bath as required to bring the fuel temperature within limits.

6.8.6 Insert into the reservoir the sintered glass aeration tube attached to the aeration tube holder. Position the diffuser so that it is touching the bottom of reservoir.

6.8.7 Using clean, dry flexible plastic tubing, connect the aeration tube to the *metered air* outlet on the left side of the JFTOT.

6.8.8 Open the '*air flow floating indicator*' control value approximately 1/8 of a turn to avoid possible excessive pressure build-up.

6.8.9 Switch 'power control' to ON.

6.8.10 Turn the 'aeration timber' control to 6 minutes.

6.8.11 Using the 'air flow valve', adjust float to green range on flowmeter (this corresponds to approximately 1·5 l/min).

6.8.12 Record on the data sheet clock time at which aeration is complete. No more than 1 hour should elapse between this time and time at which the heater switch is turned on.

6.8.13 When the 'aeration timer' has shut off the air flow, remove the aeration tube and its holder from the reservoir. Use the test fuel dripping from the aeration tube to wet piston lip seal in **6.9.1**.

6.9 Assembly of Reservoir Section

6.9.1 With the reservoir piston puller attached to the piston, wet the lip seal with filtered test fuel dripping from the aeration tube in accordance with **6.8.13**.

6.9.2 Insert the piston into the reservoir.

6.9.3 Push down on the piston puller, applying a gentle rocking motion, moving the piston downward until air leakage past the seal turns to fuel; that is, eliminate all air below the piston and lip seal. Loosen the cap seal at the end of the heater tube fuel supply line. Apply a slight downward pressure on the piston puller until fuel appears at the cap seal, and retighten the cap seal. Remove the piston puller.

6.9.4 Wet the reservoir O-ring with any fuel and place the O-ring into cover groove.

6.9.5 Place the reservoir cover on top of the fuel reservoir, taking care that the O-ring stays in the groove. Orient the cover so that the nitrogen inlet fitting on the drip flow indicator is diametrically opposite to the pre-filter fitting (*see* Note).

NOTE — Be sure that 'protector sight glass' is mounted properly over the drip flow housing.

6.9.6 Insert the cap screws into the reservoir cover holes and tighten uniformly with nut driver.

6.9.7 Flush outside of the reservoir with hexane to remove fuel.

6.9.8 Place the reservoir assembly into the cabinet so that the fore and aft bottom cap screw heads drop into positioning recesses with the pre-filter section oriented toward the heater tube section.

6.9.9 Connect the nitrogen inlet line to the side of the drip flow indicator and finger tighten snugly.

6.9.10 Connect the fuel return line to the top of the drip flow indicator and finger tighten snugly.

6.9.11 Remove the cap seal from the heater tube fuel supply line and immediately connect the line to the heater tube housing inlet. The time between removal of the cap seal and connecting should be a minimum to reduce loss of test fuel.

6.9.12 Recheck all eight knurled fittings to be sure they are tightened snugly. Recheck the thermocouple position that is, 38·7 mm position.

6.9.13 The apparatus is now ready for the test.

7. TEST PROCEDURE

7.1 Fuel System Pressurization

7.1.1 Check that the 'nitrogen pressurize' valve is *closed.*

7.1.2 Check that the 'nitrogen bleed' valve is *closed.*

7.1.3 Check that the 'manometer bypass' valve is *open.*

7.1.4 Adjust the nitrogen supply to 3·45 MN/m^2 (MPa) on the pressure regulator control gauge.

7.1.5 Open and close nitrogen pressurize valve to obtain a pressure of approximately 0·2 to 0·3 MN/m^2 (MPa). Immediately check for any obvious test section fitting leaks.

7.1.6 If a leak is apparent, immediately open the nitrogen bleed valve and take corrective action. Close the bleed valve and resume pressurization in accordance with **7.1.5.**

7.1.7 Slowly open the nitrogen pressurize valve to allow the pressure to rise to 3·45 MN/m^2 (MPa) at a rate of approximately 0·2 to 0·3 MN/m^2 per second (MPa/s).

7.1.8 Readjust the nitrogen pressure regulator if required. In making a reduction in pressure, it is necessary to have the bleed valve cracked during the adjustment.

7.2 Setting of Controls

7.2.1 Switch power control to ON.

7.2.2 Adjust the water flow to centre of green range (this corresponds to 38±8 l/h).

7.2.3 Set the timer to test time of 150 minutes.

7.2.4 Set the digital elapsed time indicator to zero.

7.2.5 Set the heater tube temperature control to the specified maximum heater tube control temperature after applying correction for any error determined in **6.2.18**. If the 'indicated melting point' of tin is below 232°C, subtract the error from the specified maximum heater tube temperature. Conversely, if the 'indicated melting point' of tin is above 232°C, add the error to the specified maximum heater tube temperature.

7.2.6 Turn the control mode switch to automatic.

7.2.7 Set the power control at 75 to 80 setting (*see* Note under **6.2.13**). The following two steps are required for recording model JFTOT's only.

7.2.8 Switch △ P alarm switch to ON. The red indicating light will come on indicating the alarm system is armed.

7.2.9 Remove the △ P recorder cover plate and check for adequate chart paper and roll about 25 mm of chart paper to give the proper index for the start of test. Push the chart mechanism into normal position, lock, and turn the switch to green (ON). Replace the cover.

7.3 Start-Up

7.3.1 Switch pump control to ON. Observe the drip flow indicator to see that flow has started, usually after 10 to 15 seconds.

7.3.2 Switch heater control to ON. Full power, approximately 250 W, is initially applied to the heater tube for a few seconds and then is automatically cut back to prevent temperature overshoot. The controller generally will bring the heater tube to the desired control temperature in less than 90 seconds.

7.3.3 When the temperature deviation meter needle centres, close the manometer bypass valve.

7.3.4 Adjust the manometer to zero. Use the top of the coated magnet as reference for recording JFTOT model.

7.3.5 Record on data sheet, the clock time the heater switch was turned ON. This time shall not be later than 1 hour after completion of fuel aeration (*see* **6.8.12**).

7.3.6 Determine the fuel flow rate with stop watch, measuring time for 20 drops. This time will be 9·0 ± 1·0 seconds. This time will vary with test fuel viscosity and surface tension.

7.3.7 For the non-recording model JFTOT, record the filter pressure drop on data sheet every 30 minutes.

7.3.8 For the recording model JFTOT, the △ P events are recorded automatically and transcribed to the data sheet at end of the test (*see* Appendix C).

7.3.9 For recording model JFTOT, if △ P reaches 125 mm and the △ P alarm is armed as in **7.2.8**, warning horn will sound. To stop horn, switch △ P alarm OFF.

7.3.10 If △ P approaches 250 mm before 150 minutes and it is desired to continue the test, open the manometer bypass valve at 245 mmHg; otherwise tester will automatically shut down (*see* Note).

NOTE — If the rig shuts down at 250 mmHg and it is desired to continue the test, open manometer bypass valve and momentarily actuate the power switch OFF-ON. This will reset both the △ P limit cutoff and the timer, resulting in the resumption of the test. However, manual shut down is required for this condition unless the timer is set for the remaining time for finishing the test.

7.3.11 *Heater Tube Temperature Profile* — If the heater tube temperature profile is specified, obtain in accordance with Appendix D.

7.4 Shut down

7.4.1 Switch pump control to OFF.

7.4.2 Switch heater control to OFF.

7.4.3 Close the nitrogen perssurize valve.

7.4.4 Open the manometer bypass valve.

7.4.5 Slowly open the nitrogen bleed valve and allow the pressure to decrease to zero at an approximate rate of 0·15 MN/m^2 per second (MPa/s).

8. DISASSEMBLY

8.1 Disconnect the heater tube fuel supply line fitting from the heater tube housing and quickly install the cap seal.

8.2 Disconnect the nitrogen and fuel return line fittings. Remove the reservoir from the test compartment, placing the reservoir in a cleaning pan.

8.3 Disconnect and remove the heater tube fuel outlet line.

8.4 Disconnect the filter bypass line.

8.5 Raise the heater tube thermocouple to the top reference mark.

8.6 Remove the right hand socket head (Allen) cap screws from each bus-bar.

8.7 Loosen the left hand socket head (Allen) cap screws three to four turns each but do not remove.

8.8 Rotate the bus-bar caps and remove the heater tube test section.

8.9 Using tweezers, remove the test filter and O-ring from the discharge chamber and discard.

8.10 Carefully remove the hexagon nuts and ceramic shoulder insulators.

8.11 Slide the heater tube out of the housing. *Do not touch tube in area that fuel contacts.* Remove and discard the O-rings. Save the ceramic insulators.

8.12 Holding the heater tube so that it points upwards from fingers, flush with hexane.

8.13 After the hexane has evaporated from the heater tube, replace the heater tube in the original container and seal with a cap. *Mark with appropriate identification.*

8.14 Remove the reservior cover and empty the fuel into the waste disposal suitable for flammable liquids.

8.15 Using a piston puller, remove the piston from the reservoir and empty any remaining fuel into waste disposal suitable for flammable liquids.

8.16 Disconnect the inlet line from the pre-filter.

8.17 Disconnect the pre-filter section from the reservoir outlet and disassemble it by removing three socket head (Allen) screws. Discard the filter element.

9. HEATER TUBE DEPOSIT RATING

9.1 Visual Method

9.1.1 Snap the upper end of the heater tube into the clamp of the adapter for the heater tube.

9.1.2 Push the heater tube against the stop of the adapter for the heater tube.

9.1.3 Slide the adapter with the heater tube over the guide rod into the Tuberator equipped with a magnifying glass assembly.

9.1.4 Insert the ASTM colour standard into the Tuberator.

9.1.5 Rotate the adapter and position the heater tube such that the side with the maximum deposit is visible.

9.1.6 Compare the maximum heater tube deposit with the ASTM colour standard. When the maximum deposit corresponds exactly to a colour standard, that number should be recorded. If the maximum heater tube deposit being rated is in the obvious transition state between any two adjacent colour standard, the rating should be reported as less than the darker (that is higher number) standard colour.

9.1.7 Return the heater tube to its original container.

9.2 Mark 8A Tube Deposit Rating Methods

9.2.1 Place the Mark 8A Tube Deposit Rater (TDR) on a table or bench, extend the front support, plug it into a suitable power point, and turn the power switch to ON position. Approximately 2 minutes are required for warm-up.

9.2.2 Remove the calibration tube from its container by pulling on the yellow cap which is attached to the calibration tube. Do not touch the tube's centre section; otherwise it will affect the calibration of the TDR.

9.2.3 Holding the calibration tube by its yellow cap, insert it into the rating rack on top of the TDR. It is necessary that the tube be pushed down firmly until it bottoms.

9.2.4 Turn the power switch to spin position.

9.2.5 Turn the tube position control to set indicator at 35 position.

9.2.6 Turn the low-cal control to obtain a tube deposit rating in accordance with the calibration printed on the calibration tube.

9.2.7 Turn the tube position control to set indicator at 50 position.

9.2.8 Turn the high-cal control to obtain a tube deposit rating in accordance with the calibration printed on the calibration tube.

9.2.9 Turn the tube position control to obtain the maximum TDR reading in the vicinity of 22 position. If the position indicator does not read 22 for the maximum TDR reading, then the calibration tube is not fully inserted or the tube position dial needs correction. See the maintenance manual for adjustment of the tube position dial.

9.2.10 Turn the power switch from spin to ON position.

9.2.11 Remove the calibration tube and insert the tube into its storage container.

9.3 Spun and Spot Deposit Methods

9.3.1 Remove the JFTOT heater tube to be rated from its container by inserting the rod of the rotation knob fully, being very careful not to touch the centre section.

9.3.2 Holding the rotation knob, insert the heater tube into the rating rack on top of the TDR. It is necessary that the heater tube be pushed down firmly until it bottoms.

9.3.3 Turn the power switch to spin position.

9.3.4 To obtain the spun deposit rating for any position, set the tube position index to the desired position and read the meter.

9.3.5 To obtain the maximum spun deposit rating, slowly scan from a tube position indicator reading of 15 to 55, stopping at the position of maximum reading. Record this reading as the maximum spun deposit rating. Do not change the tube position knob.

9.3.6 Turn the power switch to ON position.

9.3.7 Slowly rotate the heater tube manually counter clockwise 360°, stopping when the maximum obtainable meter reading is observed. Record this meter reading as the maximum spot deposit rating.

9.3.8 Replace the test heater tube in its original container and seal with a cap.

10. TEST REPORT

10.1 The report shall include the following (*see* Fig. 2).

10.1.1 The maximum heater tube temperature.

10.1.2 Heater tube deposit rating or ratings.

10.1.3 Pressure drop across the filter at the end of the test or the time required to reach a pressure differential of 250 mmHg. For the recording model JFTOT report, the maximum recorded $\triangle$ P shall be considered the $\triangle$ P at the end of test.

11. PRECISION

11.1 Precision data have not yet been established.

APPENDIX A

(*Clause* 4.1)

JET FUEL THERMAL OXIDATION TESTER

A-1. APPARATUS

A-1.1 The apparatus described in this Appendix is known as the JFTOT (jet fuel thermal oxidation tester*). It consists essentially of a closed loop fuel system with a heater tube section including a test filter together with associated equipment for controlling and measuring the heater tube temperature. Two models are available, Recording Model and Non-Recording Model. The only difference in the two models is the absence of the $\triangle$ P recorder from the latter model.

A-1.2 Certain essential accessories and materials† supplied with the tester are listed in **B-1, B-2** and **B-3**. Others not supplied with the tester are listed in **B-4**.

A-2. GENERAL DESCRIPTION

A-2.1 Figure 3 is an assembly drawing of the reservoir and pre-filter assembly.

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*At present the sole authorized manufacturer of the Jet Fuel Thermal Oxidation Tester is ALCOR, INC. 5420 Bandera Road, San Antonio, Texas 78238, USA.

†A parts list for the JFTOT may be obtained from ALCOR, Inc., San Antonio, Texas 78238, USA.

A-2.2 Figure 4 is an assembly drawing of the heater tube section.

A-2.3 Figure 6 is a drawing of the test section compartment.

A-2.4 Figure 7 is a schematic diagram of the fuel system.

A-2.5 Figure 8 is a schematic diagram of the heater tube power and temperature control systems.

A-3. FUEL SYSTEM

A-3.1 Test fuel contained in the reservoir is passed through the test section by a constant displacement pump located downstream of the heater tube section to preclude contamination by pump wear particles. The pump is driven by a constant speed motor so as to have a displacement of 3·0 cm^3/minute.

A-3.2 From the reservoir outlet, the fuel flows through a 0·45μm nominal pore size membrane type filter, thence to the lower (inlet) part of the heater tube section. The heater tube is connected between two bus bars and is electrically insulated from the outer housing by means of a ceramic ferrule/O-ring seal combination. The fuel rises vertically in the annular space between the aluminium heater tube and its outer stainless steel housing. A low-voltage, high-current ac signal is passed through the heater tube so as to obtain resistance heating. After leaving the heater tube section, the fuel passes through a test filter having an element made from stainless steel cloth with a nominal pore size of 17 μm.

A-3.3 A mercury manometer is connected so as to measure pressure drop across this filter. In $\triangle$ P Recorder Model, the $\triangle$ P *versus* time relation is automatically recorded. The test filter can be bypassed at any time, normally this is done when $\triangle$ P reaches 250 mmHg. The fuel reaches the cooler either directly or through the bypass and proceeds through the metering pump to return to the fuel reservoir. A sight gauge drip flow indicator allows visual monitoring of the flow rate. Return fuel is isolated from the test fuel by a piston with a lip seal.

A-4. HEATING AND TEMPERATURE CONTROL SYSTEM

A-4.1 The heater tube is heated by the passage of an electrical current of approximately 200 to 300 A at 0·3 to 0·5 V. The heater tube is clamped at each end into bus bars having gold plated contact surfaces. The bus bars are cooled by internal water lines. The bus bars receive electrical power from a low voltage transformer having a step-down ratio to match the electrical resistance of the heater tube.

A-4.2 When the tester is operated in the automatic mode the temperature is under automatic control and the control unit also acts as the temperature indicator. When the tester is operated in the manual mode the control unit acts only as a temperature indicator and the temperature is controlled manually by operation of the power control. The input signal to the controller is from a thermocouple inserted through the top of the heater tube and positioned at the point of maximum temperature. This thermocouple can be positioned at any point along the heated portion of the tube for the purpose of obtaining a temperature profile. An indicator is provided to define the position of the thermocouple junction with 0·0 station being the heater tube's lower shoulder. A wattmeter measures electrical power supplied to the low voltage transformer and, therefore, indicates total power consumed by the heater tube plus bus connecter, transformer, and line losses. A variable voltage transformer, labeled power control, having a dual function, controls the maximum voltage and is the only control when in the manual mode. The power control has a removable stop to limit the power so as to prevent melting of the heater tube in the event that the operator neglects to insert the thermocouple into the heater tube. When the desired maximum tube temperature (greater than about 343°C) cannot be obtained with the power control against this stop, it may be removed. A constant voltage transformer is supplied with each tester to compensate for line voltage fluctuations.

A-5. COOLING SYSTEM

A-5.1 Ordinary tap water at any pressure between 200 and 700 kN/m^2(kPa) is required for bus connector cooling. The JFTOT has a flow adjustment valve and a floating index type flow indicator to set the rate at 38 ± 8 l/h. After entering the cabinet, the water flows through a filter adequate to remove any solid particles that could plug the lines with time or interfere with the operation of the solenoid valve which is normally closed and opens when the power switch is turned on. A water pressure switch is in the power line to the pump motor and heater and is normally open, closing only when the water pressure rises above 140 kN/m^2 (kPa) and opening (turning heater and pump off) if water pressure drops below this value. The water next flows through a heat exchanger used to cool the fuel prior to entering the pump. After this, the water passes through copper tubing internally silver soldered to the buses. The water lines are electrically insulated from the bus connectors by means of polyethylene tubing.

A-6. FUEL PRESSURIZATION SYSTEM

A-6.1 Compressed nitrogen from a cylinder fitted with a pressure regulator is used to provide a pressure of 3·45 MN/m^2 (MPa) in the fuel system. All system components have been tested to 6·9 MN/m^2 (MPa).

A-6.2 For safety, an adjustable pressure limiter is provided in the nitrogen inlet line and is set at approximately 3·7 MN/m^2 (MPa). Two nitrogen control needle valves marked 'Pressurize' and 'Bleed' are provided. Their function is evident from the schematic diagram (*see* Fig. 7).

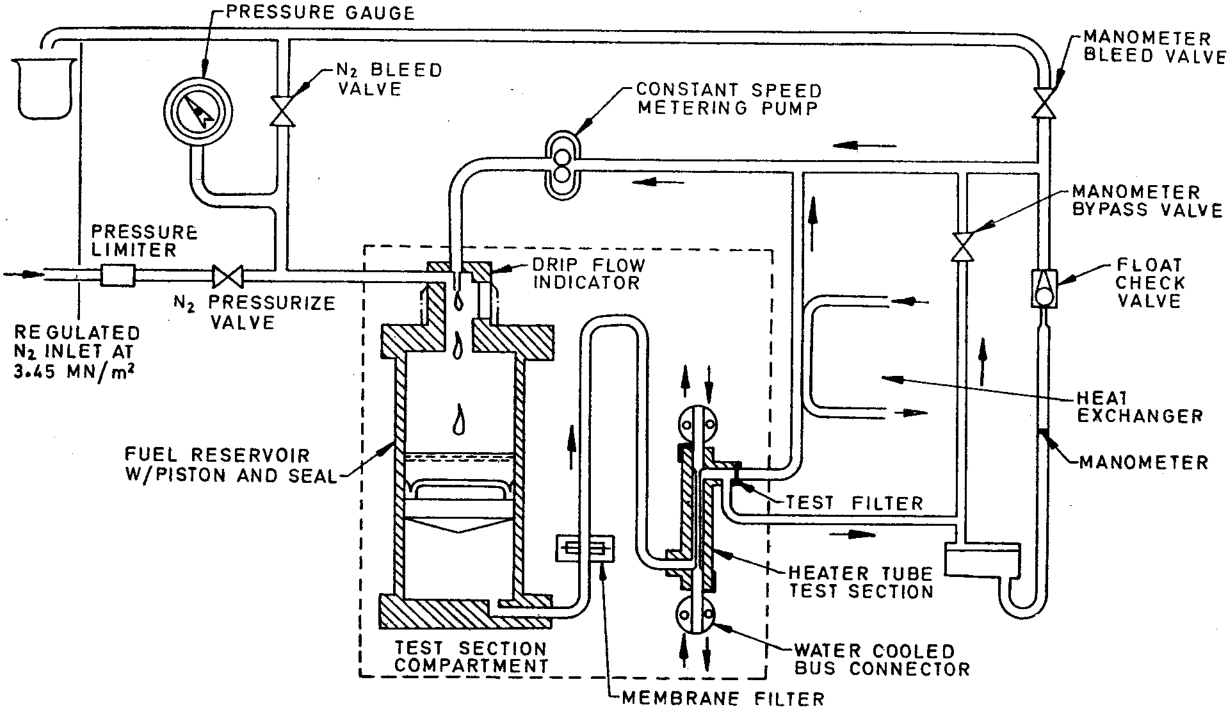

Fig. 7 Schematic Diagram of the Fuel System

A-7. MANOMETRY SYSTEM

A-7.1 A single leg 305 mm mercury manometer is connected across the test filter to measure filter pressure drop as the filter fouls with products of fuel degradation. A manual valve labeled 'Man Bypass' permits the fuel to bypass the test filter when 250 mmHg $\triangle$P occurs before the time set to obtain heater tube deposits for the fuel test period. A float type check valve in the low pressure leg of the manometer prevents mercury from 'going over the top' during abnormally high differential pressure surges and consequently contaminating the fuel system. This could happen only by applying an excessively rapid rate of pressurization or failure of the automatic system to shut the rig down at 250 mmHg $\triangle$ P. A manual valve labeled 'Man Bleed' is provided to bleed and eliminate readily any air or nitrogen from the manometer system whenever required.

A-7.2 In the recording model, automatic recording of $\triangle$ P *versus* time is obtained with a 10 channel event recorder which has dual speeds of 60 and 360 mm/h. Normal speed is 60 mm/h. Reed type switches at stations 2, 10, 15, 25, 50, 75, 125 and 250 mmHg are mounted adjacent to the manometer tube and are activated by a small plastic-enclosed magnet floating on top of the mercury column. As $\triangle$ P increases, the magnet activates each switch in turn and the resulting signal records, the event on the appropriate channel of the event recorder. A $\triangle$ P warning system sounds a horn when the $\triangle$ P reaches 125 mmHg to alert the operator of impending shutdown at 250 mmHg. The $\triangle$ P alarm system controls are located at the top of the manometer cover and consist of an ON-OFF switch, a red light to show that the system is armed, and a high frequency horn. When the $\triangle$ P reaches 250 mmHg, the reed switch action cuts off the power to the metering pump, heater tube and timing devices; all other devices such as the blower and solenoid remain ON until the power switch is turned manually to OFF.

A-8. THERMOCOUPLE CALIBRATION SYSTEM

A-8.1 The AutoCal calibration system provides for a reliable check of the calibration of the entire temperature indication system by utilizing the freezing point, 232°C, of 99·99 percent pure tin as the standard. The AutoCal calibrator consists of a special heater tube which has at its middle section a small well containing pure tin into which the thermocouple is immersed. The test thermocouple is introduced into the tin after raising the temperature above the melting point and the cool-down temperature-time characteristic is observed by the operator who notes the temperature indication at which the temperature controller deviation meter needle pauses. Any difference between this reading and 232°C is the error in the temperature measurement system and shall be applied as a correction when setting the maximum heater tube control temperature and when plotting a heater tube temperature profile.

A-9. FUEL AERATION SYSTEM

A-9.1 A system is provided to air saturate the test portion in the reservoir prior to test. A floating index flow control and automatic timer-cut-off are set to pass dry, filtered air at 1·5 l/min for 6 minutes. The 9·0 litres thus passed through the fuel ensures at least 97 percent of air saturation.

A-10. ELAPSED TEST TIME MEASUREMENT

A-10.1 There are at least two indications of elapsed test time in the manual model, a digital readout indicator (to nearest 0·1 minute) and a timer-cut-off (to nearest 3 minutes) which can be set to cut off at any specified time up to 5·0 hours. In the recording model JFTOT the automatic $\triangle$ P recorder provides yet a third measure of elapsed test time.

A-11. LABORATORY INSTALLATION REQUIREMENTS

A-11.1 The tester should be placed on a level laboratory bench, allowing 200 to 300 mm wide bench area in front of the tester. Ready access to the rear of the tester should be provided for normal maintenance and service requirements. Ensure that the vent on top of the JFTOT cabinet is not obstructed during installation or use. The constant voltage transformer shall be plugged into the left side of the tester and can be placed either adjacent to the tester or preferably under the bench. Single-phase electrical power, 115V, 60 Hz, 15 A or optional 220V, 50 Hz, 8 A with a ground (earth) outlet is required.

A-11.2 A nitrogen cylinder with a suitable regulator capable of supplying at 3·45 MN/m^2 (MPa) should be placed conveniently and connected with 3·2 mm diameter tubing to the tester. A suitable 6·4 mm diameter line needs to be connected from the water inlet connection to a 200 to 700 kn/m^2 (kPa) water supply and a 6·4 mm diameter line needs to be connected from water drain to a drain having a minimum capacity to receive 80 l/h.

APPENDIX B

(*Clause* 4.3)

MATERIALS SUPPLIES AND SPARES

B-1. The following items are supplied with each JFTOT:

1) Magnifying assembly for tuberator
2) Tuberator adapter for heater tube
3) AutoCal heater assembly
4) Piston puller
5) Cap seal

6) Aeration tube
7) Clear plastic tubing for aeration tube
8) Aeration tube holder
9) Funnel holder
10) Nut driver, 12·7 mm
11) Socket head (Allen) screw driver, 4 mm
12) Power cord
13) Constant-voltage transformer 60 Hz or 50 Hz
14) Step-down transformer, 230/115 V (*see* Note)

NOTE — These are supplied only with 230 V, 50 Hz (JFTOT).

15) Protector, sight glass

B-2. The following items are required to be replaced for each test and therefore shall be stocked in accordance with volume of testing involved:

1) Heater tube and filter kit
2) Pre-filter element
3) Data sheets (*see* Fig. 2)

B-3. The following supplies are spare parts needing periodic replacement as required and should therefore be stocked in accordance with volume of testing involved:

1) Ceramic insulators (4 per set)
2) Lip seal, reservoir piston
3) O-ring, reservoir
4) O-ring, sight glass
5) O-ring, retention screw
6) O-ring, line connections
7) O-ring, pre-filter
8) Thermocouple assembly
9) Tin, 99·99 percent pure pellets in capsules containing 1·6±0·5 g
10) Metering pump
11) Chart paper, △ P recorder
12) Aeration tube

B-4. The following additional items are not supplied with the JFTOT but are required for normal operation:

1) ALCOR Mark 8A Tube Deposit Rater
2) EPPI Tuberator
3) Nitrogen, compressed cylinder
4) Pressure regulator 0 to 7 MN/m^2 (MPa)
5) Hexane, technical grade, 95 mol percent minimum purity

6) Disposable gloves
7) Trisolvent (equal parts by volume of toluene, acetone, and propan-2-ol (isopropyl alcohol, 99 percent purity)
8) Wash bottle, polyethylene
9) Cleaning pan, stainless steel (250 × 350 mm, *Min*)
10) Brush, nylon (40 × 100 mm)
11) Brush, nylon (15 × 75 mm)
12) Funnel, glass
13) Thermometer, glass conforming to the essential requirements given below:

Range	–38 to +50°C
Graduation	1°C
Immersion, mm	108
Overall length, mm	225 to 235
Stem diameter, mm	6·0 to 8·0
Bulb shape	—
Bulb length, mm	7 to 10
Bulb diameter, mm	5·5 to 8·0
Length of graduated portion, mm	65 to 85
Bottom of bulb of graduation at	–38°C
Distance, mm	120 to 130
Longer lines at each	5°C
Figured at each	10°C
Expansion chamber	100°C
Top finish	—
Scale error, *Max*	0·5°C

14) Tweezers, flat bladed, non serrated
15) Rubber squeeze bulb
16) Extractor for ceramic insulators
17) Silicone grease
18) Paper tissues
19) Aluminium foil, about 450 mm wide
20) Graduated cylinder, capacity 1 000 ml
21) General-purpose, retentive, qualitative filter paper

APPENDIX C

(*Clause* 7.3.8)

△ P EVENT RECORDER

C-1. Before utilizing the △ P event recorder, familiarization with the instruction manual for the Model 2755 Ten channel event recorder is required. This manual is furnished with each JFTOT. The △ P events are recorded in sequence by styli which move at right angles to the chart's direction of motion. Normal chart speed is 60 mm/h with chart subdivisions spacing every 5 minutes. Channel 1 records the start and the end of the test; that is, heater ON and OFF events. The chart drive is also actuated by the heater ON or OFF function. Channel 2 through 8 record 2, 10, 15, 25, 50, 75 and 125 mmHg △ P. If △ P reaches 250 mmHg, automatic shutdown is actuated, which also stops recorder chart drive. After completion of test, remove that portion of the chart that is applicable to the test and with pencil or pen emphasize locations where styli are first activated by movement to the right. Interpret the time after start of test that activation occurred for each △ P channel and record on the data sheet.

APPENDIX D

(*Clause* 7.3.11)

HEATER TUBE TEMPERATURE PROFILE

D-1. Data are presented in Table 1 (*see* P 31) to permit establishing the heater tube temperature profile for maximum heater tube temperatures from 200 to 370°C. If it is desired to measure the heater tube temperature profile the following procedure should be followed after the second half hour of the test or before a significant △ P has been obtained (*see* Fig. 8).

D-2. Observe the wattmeter reading and simultaneously switch the controller to manual mode and reduce power control to previously observed wattmeter reading. Fine-adjust the power control to place temperature deviation meter needle at exact centre of the scale and let it stabilize. If no temperature drift is observed for 30 seconds, proceed to the next step.

D-3. Set the thermocouple in sequence to the following positions to obtain their respective temperatures:

Position mm
56
50
44
38·7
32
26
18
10

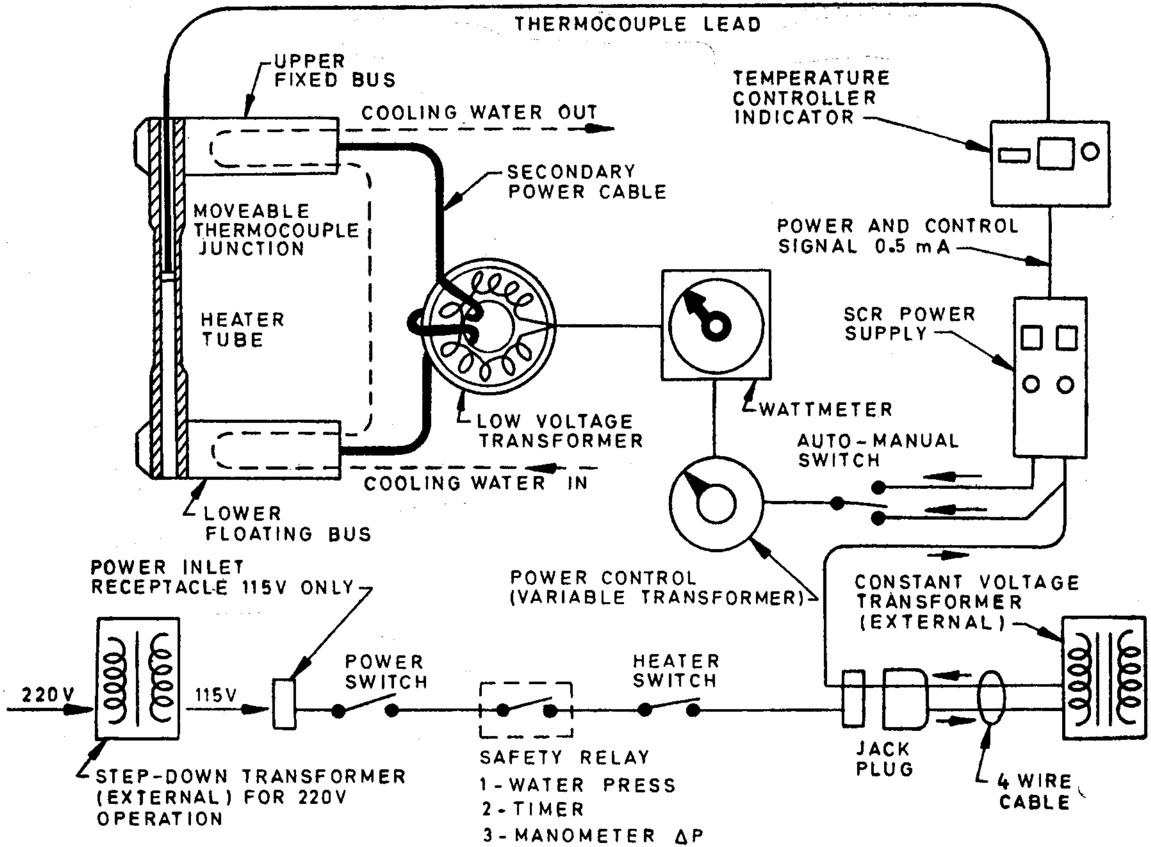

Fig. 8 Heater Tube Power and Temperature Control Schematic

At each position, adjust the digital set point control on the temperature indicator to centre the deviation meter needle. Allow at least 5 seconds for temperature stabilization before recording the indicated temperature.

D-4. If temperature at the 38·7 mm position has drifted more than ±2°C from initial value, read just the power control and begin again at the 56 mm position after the temperature at the 38·7 mm position has become stable at the initial value. If drift is less than ±2°C, readjust power control and proceed to the 32 mm position.

D-5. Return the thermocouple to the 38·7 mm position. Again, if this temperature has drifted in excess of ±2°C, reset manually and repeat the above procedure.

D-6. Simultaneously switch the temperature controller to automatic mode and adjust the power control to 75 to 80 settings (*see* Note under **6.2.13**).

D-7. Correct recorded temperatures for error in accordance with **7.2.5**.

D-8. Continue the test.

APPENDIX E

(*Clauses* 6.2.16, 6.2.17 *and* 6.6.16)

MAINTENANCE

E-1. AUTOCAL CALIBRATOR TIN REPLACEMENT

E-1.1 The tin in the well of the AutoCal calibrator shall be replaced whenever the quantity is below the minimum or when the tin has become contaminated.

E-1.2 To remove the tin, install the AutoCal calibrator inverted between the upper fixed bus bar and the lower floating bus bar.

E-1.3 Place a paper tissue or rag under the well to catch the molten tin.

E-1.4 Apply power to the AutoCal calibrator in accordance with **6·2** and at the same time gently tap the well until all molten tin has dropped out.

E-1.5 Remove the AutoCal calibrator and install it in upright position and refill with new tin charge. The proper amount of tin for one filling is furnished in a capsule (1·6±0·5 g) [*see* **B-3.(9)**].

E-2. THERMOCOUPLE REPLACEMENT AND POSITION ADJUSTMENT

E-2.1 The thermocouple used for measuring and controlling the temperature of the JFTOT heater tube needs replacement at intervals due to insulation abrasion or other damage to the insulation or thermocouple element.

E-2.2 To remove the thermocouple, loosen the thermocouple clamp, support clamp, and thermocouple connections on back of the temperature controller.

E-2.3 Install a new thermocouple following the same routing as old thermocouple. Replace and tighten screws. When tightening the socket head (Allen) screw of thermocouple clamp, the tip of the thermocouple shall be flush with top of upper fixed bus bar when the position indicator is set at the reference mark.

E-2.4 Check for proper thermocouple indexing under actual test operating conditions.

E-2.5 Operate the JFTOT at some control temperature with the new thermocouple at the 38·7 mm position. The control temperature chosen is not critical, but shall be between 200 and 370°C.

E-2.6 Change to the manual mode for temperature control following the instructions in **D-2** and observe temperature at the 18 mm position in accordance with **D-3**. If the observed temperature at the 18 mm position is not within 1°C of the value in Table 1, adjustment of the thermocouple position is necessary.

E-2.7 To adjust the thermocouple, loosen the socket head (Allen) screw of the thermocouple clamp, without moving the position index, move the thermocouple until a reading within 1°C of the Table 1 value is obtained. Tighten the socket head (Allen) screw snugly.

E-2.8 Return index to the 38·7 mm position and observe temperature. If the observed temperature differs by more than 0·5°C from the value selected in **E-2.5**, readjust the power control to obtain the selected control temperature. If a power adjustment was necessary, recheck the temperature at the 18 mm position which should be within 1°C of the Table 1 value.

E-2.9 Repeat steps **E-2.7** and **E-2.8** until alternate reading at the 38·7 mm and 18 mm positions are within 0·5°C and 1°C, respectively, of the table values.

E-3. MAINTENANCE MANUAL

E-3.1 A maintenance manual providing additional information to that given in this appendix is available from the equipment supplier. It includes an electrical circuit diagram, which will also be found inside the back door of the JFTOT cabinet, a parts list and the settings of the tube position index knob for the Mark 8A tube deposit rater.

TABLE 1 JFTOT STANDARD TEMPERATURE PROFILES

(*Clauses* D-1 *and* E-2·6)

MAXIMUM TEMPERATURES

STATION	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240	242
10·0	139	140	142	143	144	145	146	147	149	150	151	152	153	155	156	157	158	159	160	162	163	164
12·0	147	148	149	150	152	153	154	156	157	158	159	161	162	163	165	166	167	168	170	171	172	173
14·0	154	155	156	158	159	160	162	163	165	166	167	169	170	171	173	174	176	177	178	180	181	182
16·0	160	162	163	165	166	167	169	170	172	173	175	176	178	179	181	182	184	185	186	188	189	191
18·0	166	168	169	171	172	174	176	177	179	180	182	183	185	186	188	189	191	192	194	196	197	199
20·0	172	174	175	177	178	180	182	183	185	186	188	190	191	193	195	196	198	199	201	203	204	206
22·0	177	179	180	182	184	186	187	189	191	192	194	196	197	199	201	202	204	206	207	209	211	213
24·0	182	184	185	187	189	191	192	194	196	198	199	201	203	205	206	208	210	212	213	215	217	219
26·0	186	188	190	191	193	195	197	199	200	202	204	206	208	210	211	213	215	217	219	220	222	224
28·0	190	192	193	195	197	199	201	203	205	206	208	210	212	214	216	218	219	221	223	225	227	229
30·0	193	195	197	199	201	202	204	206	208	210	212	214	216	218	220	221	223	225	227	229	231	233
32·0	196	198	199	201	203	205	207	209	211	213	215	217	219	221	223	225	227	229	230	232	234	236
34·0	198	200	202	204	206	208	209	211	213	215	217	219	221	223	225	227	229	231	233	235	237	239
36·0	199	201	203	205	207	209	211	213	215	217	219	221	223	225	227	229	231	233	235	237	239	241
38·0	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240	242
38·7	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240	242
40·0	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240	242
42·0	198	200	202	204	206	208	210	212	214	216	218	220	222	224	226	228	230	232	234	236	238	240
44·0	196	198	200	202	204	206	208	210	212	214	216	218	220	222	223	225	227	229	231	233	235	237
46·0	192	194	196	198	200	202	204	206	208	209	211	213	215	217	219	221	223	225	227	229	231	233
48·0	187	189	191	192	194	196	198	200	202	204	206	208	210	211	213	215	217	219	221	223	225	227
50·0	180	182	184	186	187	189	191	193	195	197	198	200	202	204	206	208	210	211	213	215	217	219
52·0	172	174	175	177	179	181	183	184	186	188	190	192	193	195	197	199	200	202	204	206	208	209
54·0	162	164	166	167	169	171	172	174	176	178	179	181	183	185	186	188	190	191	193	195	197	198
56·0	151	153	154	156	158	159	161	162	164	166	167	169	171	172	174	176	177	179	180	182	184	185

(Continued)

TABLE 1 JFTOT STANDARD TEMPERATURE PROFILES—*Contd*

	Maximum Temperatures																					
Station	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284
10·0	164	165	166	168	169	170	171	172	173	175	176	177	178	179	180	182	183	184	185	186	188	189
12·0	173	175	176	177	179	180	181	182	184	185	186	188	189	190	191	193	194	195	196	198	199	200
14·0	182	184	185	187	188	189	191	192	193	195	196	198	199	200	202	203	204	206	207	209	210	211
16·0	191	192	194	195	197	198	200	201	203	204	205	207	208	210	211	213	214	216	217	219	220	222
18·0	199	200	202	203	205	206	208	209	211	213	214	216	217	219	220	222	223	225	226	228	230	231
20·0	206	208	209	211	212	214	216	217	219	220	222	224	225	227	229	230	232	233	235	237	238	240
22·0	213	214	216	218	219	221	223	224	226	228	229	231	233	235	236	238	240	241	243	245	246	248
24·0	219	220	222	224	226	227	229	231	233	234	236	238	240	241	243	245	247	248	250	252	254	255
26·0	224	226	228	229	231	233	235	237	238	240	242	244	246	248	249	251	253	255	257	258	260	262
28·0	229	231	233	234	236	238	240	242	244	246	247	249	251	253	255	257	259	260	262	264	266	268
30·0	233	235	237	239	241	242	244	246	248	250	252	254	256	258	260	261	263	265	267	269	271	273
32·0	236	238	240	242	244	246	248	250	252	254	256	258	260	262	263	265	267	269	271	273	275	277
34·0	239	241	243	245	247	249	251	253	255	257	259	261	263	265	267	269	270	272	274	276	278	280
36·0	241	243	245	247	249	251	253	255	257	259	261	263	265	267	269	271	273	275	277	279	281	283
38·0	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284
38·7	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284
40·0	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282	284
42·0	240	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274	276	278	280	282
44·0	237	239	241	243	245	247	249	251	253	255	257	259	261	263	265	267	269	271	273	275	277	279
46·0	233	235	237	239	241	242	244	246	248	250	252	254	256	258	260	262	264	266	268	270	272	274
48·0	227	229	230	232	234	236	238	240	242	244	246	248	249	251	253	255	257	259	261	263	265	267
50·0	219	221	223	224	226	228	230	232	234	236	237	239	241	243	245	247	248	250	252	254	256	258
52·0	209	211	213	215	217	218	220	222	224	226	227	229	231	233	234	236	238	240	242	243	245	247
54·0	198	200	202	203	205	207	209	210	212	214	215	217	219	221	222	224	226	227	229	231	233	234
56·0	185	187	189	190	192	194	195	197	198	200	202	203	205	207	208	210	212	213	215	216	218	220

(Continued)

TABLE 1 JFTOT STANDARD TEMPERATURE PROFILES—*Contd*

Maximum Temperatures

STATION	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322	324	326
10·0	189	190	191	192	193	195	196	197	198	199	200	202	203	204	205	206	208	209	210	211	212	213
12·0	200	202	203	204	205	207	208	209	211	212	213	214	216	217	218	219	221	222	223	225	226	227
14·0	211	213	214	215	217	218	219	221	222	224	225	226	228	229	230	232	233	235	236	237	239	240
16·0	222	223	224	226	227	229	230	232	233	235	236	238	239	241	242	243	245	246	248	249	251	252
18·0	231	233	234	236	237	239	240	242	243	245	247	248	250	251	253	254	256	257	259	260	262	263
20·0	240	242	243	245	246	248	250	251	253	255	256	258	259	261	263	264	266	267	269	271	272	274
22·0	248	250	251	253	255	256	258	260	262	263	265	267	268	270	272	273	275	277	278	280	282	284
24·0	255	257	259	261	262	264	266	268	269	271	273	275	276	278	280	282	283	285	287	289	290	292
26·0	262	264	266	267	269	271	273	275	277	278	280	282	284	286	287	289	291	293	295	296	298	300
28·0	268	270	272	273	275	277	279	281	283	285	286	288	290	292	294	296	298	299	301	303	305	307
30·0	273	275	277	279	280	282	284	286	288	290	292	294	296	298	300	301	303	305	307	309	311	313
32·0	277	279	281	283	285	287	289	291	293	295	296	298	300	302	304	306	308	310	312	314	316	318
34·0	280	282	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322
36·0	283	285	287	289	291	293	295	297	299	301	303	305	307	308	310	312	314	316	318	320	322	324
38·0	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322	324	226
38·7	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322	324	326
40·0	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322	324	326
42·0	282	284	286	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320	322	324
44·0	279	281	283	285	287	288	290	292	294	296	298	300	302	304	306	308	310	312	314	316	318	320
46·0	274	275	277	279	281	283	285	287	289	291	293	295	297	299	301	303	305	306	308	310	312	314
48·0	267	268	270	272	274	276	278	280	282	284	286	287	289	291	293	295	297	299	301	303	305	306
50·0	258	260	261	263	265	267	269	271	273	274	276	278	280	282	284	285	287	289	291	293	295	297
52·0	247	249	251	252	254	256	258	260	261	263	265	267	268	270	272	274	276	277	279	281	283	285
54·0	234	236	238	240	241	243	245	246	248	250	252	253	255	257	258	260	262	264	265	267	269	270
56·0	220	221	223	225	226	228	230	231	233	234	236	238	239	241	243	244	246	248	249	251	252	254

(Continued)

TABLE 1 JFTOT STANDARD TEMPERATURE PROFILES—*Contd*

MAXIMUM TEMPERATURES

STATION	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368	370
10·0	213	215	216	217	218	219	220	222	223	224	225	226	228	229	230	231	232	233	235	236	237	238	239
12·0	227	228	230	231	232	234	235	236	237	239	240	241	242	244	245	246	248	249	250	251	253	254	255
14·0	240	241	243	244	246	247	248	250	251	252	254	255	257	258	259	261	262	263	265	266	268	269	270
16·0	252	254	255	257	258	260	261	262	264	265	267	268	270	271	273	274	276	277	278	280	281	283	284
18·0	263	265	267	268	270	271	273	274	276	277	279	280	282	284	285	287	288	290	291	293	294	296	297
20·0	274	276	277	279	280	282	284	285	287	289	290	292	293	295	297	298	300	301	303	305	306	308	310
22·0	284	285	287	289	290	292	294	295	297	299	300	302	304	305	307	309	311	312	314	316	317	319	321
24·0	292	294	296	298	299	301	303	305	306	308	310	312	313	315	317	319	320	322	324	326	327	329	331
26·0	300	302	304	305	307	309	311	313	315	316	318	320	322	324	325	327	329	331	333	334	336	338	340
28·0	307	309	311	313	314	316	318	320	322	324	326	327	329	331	333	335	337	339	340	342	344	346	348
30·0	313	315	317	319	320	322	324	326	328	330	332	334	336	338	340	341	343	345	347	349	351	353	355
32·0	318	320	322	324	326	327	329	331	333	335	337	339	341	343	345	347	349	351	353	355	357	359	360
34·0	322	324	326	328	330	332	333	335	337	339	341	343	345	347	349	351	353	355	357	359	361	363	365
36·0	324	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368
38·0	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368	370
38·7	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368	370
40·0	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368	370
42·0	324	326	328	330	332	334	336	338	340	342	344	346	348	350	352	354	356	358	360	362	364	366	368
44·0	320	322	324	326	328	330	332	334	336	338	340	342	344	346	348	350	352	353	355	357	359	361	363
46·0	314	316	318	320	322	324	326	328	330	332	334	336	338	339	341	343	345	347	349	351	353	355	357
48·0	306	308	310	312	314	316	318	320	322	324	325	327	329	331	333	335	337	339	341	343	344	346	348
50·0	297	298	300	302	304	306	308	310	311	313	315	317	319	321	323	324	326	328	330	332	334	335	337
52·0	285	286	288	290	292	294	295	297	299	301	303	304	306	308	310	311	313	315	317	319	320	322	324
54·0	270	272	274	276	277	279	281	282	284	286	288	289	291	293	295	296	298	300	301	303	305	307	308
56·0	254	256	257	259	261	262	264	266	267	269	270	272	274	275	277	279	280	282	284	285	287	288	290

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